COMPUTATIONAL DISCRETE DISLOCATION PLASTICITY

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The main mechanism of plastic flow in crystalline metals is the collective motion of dislocations. In discrete dislocation plasticity, this collective motion is accounted for directly. The dislocations are represented as displacement discontinuities in a linear elastic medium. Plastic deformation then involves moving singularities in a linear elastic solid. Boundary value problems are solved by writing the stress and displacement fields as superpositions of fields due to the discrete dislocations, which are singular inside the body, and image fields that enforce the boundary conditions. This leads to a linear elastic boundary value problem for the smooth image fields that can be solved by standard numerical techniques. Thus, the long range interactions between dislocations are accounted for through the continuum elasticity fields. Short range interactions are accounted for through constitutive rules. The stress-strain response and the dislocation structures that emerge are outcomes of a boundary value problem solution and hence depend on the imposed loading. The computational framework for solving boundary value problems is described, with a focus on the numerical challenges involved. In particular, when finite shape changes are accounted for, the displacement field is not continuous. The suitability of conventional finite element methods for analyzing finite deformation discrete dislocation plasticity problems is discussed. Various boundary value problem solutions are used to illustrate characteristic features of discrete dislocation plasticity, with particular attention given to features not embodied in conventional phenomenological theories of plasticity. These include the emergence of boundary layers and size effects, dislocation pattern formation, source limited plasticity, chaotic behavior and hysteresis leading to fatigue.

References

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